Modeling of micromachined acoustic bandgap structures and devices

I. El-Kady, J.G. Fleming, R. H. Olsson III, and T.S. Luk
Sandia National Laboratories, Albuquerque, New Mexico, USA.

Acoustic Bandgap (ABG) crystals, when combined with electro-acoustic couplers, enable a number of new devices from high performance acoustic isolators to novel acoustic signal processors with performance not yet achievable on the micro-scale. The homomorphism which connects acoustic phonons to optical photons is used as the bases for the construction of the acoustic devices. Unlike photonic crystals however, the mechanical wave nature and low coupling to air modes along with the possibility of vacuum packaging allow for full wave control using only 2D devices.

The simplest device is an acoustic reflector, useful for isolating high Q components such as resonators and gyroscopes from the anchoring substrate. These ABG isolators remove quarter wave beam anchors, improving power handling and dynamic range. In devices that already use 1D acoustic reflectors, the much wider bandwidth (> 10x) and improved isolation provided by the ABG structures increases Q, allows for mismatch between components and allows multiple devices to be isolated using the same ABG.

In order to guide the fabrication effort we have adopted a finite-difference time-domain (FDTD) algorithm for the temporal integration of the full elastic wave equation that incorporates both Lame coefficients. Different crystallographic arrangements of the ABG scatteres are studied and optimal geometries are identified. Good agreement between theoretical and experimental results is observed.

Optimization of the acoustic gaps and device functionality can be further enhanced by customization of well established optimization techniques developed by our group for use in photonic crystal device applications. Here derivative based optimization is used as a precurser for genetic algorithm based searches to minimize the computational time. Multi-objective as well as multi-domain optimization can also be implemented to derive optimal structural topology search within fabrication limits.